

RECEIVER, RECEIVING METHOD, AND RECORDING MEDIUM WHICH
RECORDS PROGRAM FOR RECEIVING DATA SIGNALS

BACKGROUND OF THE INVENTION

Field of the Invention

5 The present invention relates to a receiver, signal receiving method, and information recording medium which records a program for receiving data signals. More particularly, the present invention relates to a receiver and method for desirably estimating transmission path characteristics when to transmit a signal including a data signal and a known signal, compensating for the signal, and suitably obtaining the
10 transmitted data signal, and also to a computer readable recording medium which records a program for realizing the receiver and method in a computer.

Description of the Related Art

In recent years, in the field of radio communications, it is more demanded that a large amount of data are transmitted. In response to this demand, various techniques
15 have been studied.

Since delayed waves may occur as a result of reflection caused by an electro-magnetic wave obstacle in a transmission path, it is necessary to eliminate any undesired effects of the occurring delayed waves. In consideration of this, the following technique is proposed.

20 On the transmitter side, data symbols to be transmitted are modulated together with a known symbol, so as to be transmitted.

On the receiver side, a portion of a received signal which corresponds to the known symbol is compared with a resultant signal obtained by modulating the known symbol, so as to obtain an impulse response. Thus obtained impulse response is estimated as
25 transmission path characteristics. Further, a portion of the received signal which corresponds to the data symbol is compensated using the estimated transmission path characteristics, and demodulated, so as to obtain the transmitted data symbol.

Such a technique is used in the OFDM (Orthogonal Frequency Division Multiplexing) communications.

To transmit a large amount of data through a mobile radio LAN (Local Area Network), it is desirable that the length of the transmitted data symbol is larger than the
 5 length of the known symbol as much as possible. In the field of mobile data communications, transmission contexts between a terminal and another terminal and between a terminal and a base station may widely change.

According to the above-described technique, the transmission path characteristics change as time goes by. In such circumstances, the estimated value of the transmission
 10 path characteristics may be quite far from the actual contexts while transmitting a data symbol which is large in length. A problem arises in that the data can not sufficiently be compensated.

SUMMARY OF THE INVENTION

The present invention has been made in consideration of the above. It is
 15 accordingly an object of the present invention to provide a receiver and method for desirably estimating transmission path characteristics when to transmit a signal including a data signal and a known signal, compensating for the signal, and suitably obtaining the transmitted data signal, and also to a computer readable recording medium which records a program for realizing the receiver and method in a computer.

20 In order to accomplish the above object, according to the first aspect of the present invention, there is provided a receiver comprising a receiving section, an estimation section, a compensation section, a demodulation section, and a modulation section.

The receiving section receives a resultant signal obtained by transmitting a transmission signal obtained by modulating a signal including a known signal and a data
 25 signal, and output the received resultant signal as a received signal.

The estimation section estimates transmission path characteristics.

The compensation section compensates for a portion of the received signal, which

corresponds to the data signal, using the transmission path characteristics estimated at the compensation section, and outputs the compensated signal as a compensated data signal.

The demodulator demodulates the compensated data signal, and outputs the demodulated signal as a demodulated data signal.

- 5 The modulation section modulates the demodulated data signal, and outputs the modulated signal as a modulated data signal.

The estimation section

(a) compares a portion of the received signal which corresponds to the known signal with a resultant signal obtained by modulating the known signal, and

- 10 (b) compares the portion of the received signal which corresponds to the data signal with a portion of the modulated data signal which corresponds to the data signal, thereby to estimate the transmission path characteristics.

In the receiver of this invention, a portion of the received signal which has not yet been compensated may be compensated using a portion of the transmission path

- 15 characteristics which have already been estimated.

In the receiver of this invention, the estimation section may output impulse responses which are obtained by performing (a) and (b), as transmission path characteristics.

- The modulation section may modulate the known signal, and outputs the modulated
20 signal as a modulated-known signal.

The estimation section may perform (a) and (b), using the modulated-known signal, as a resultant signal obtained by modulating the known signal.

- In the receiver of this invention, the transmission signal may be obtained by modulating the signal including the known signal and data signal, using the multi-carrier
25 transmission technique, and include a divider.

The divider may divide the received signal at each carrier frequency according to the multi-carrier transmission technique, and outputs the divided signals as a group of

received signals.

The receiver may use the group of received signals in place of the received signal, a group of compensated data signals in place of the compensated data signal, a group of demodulated data signals in place of the demodulated data signal, a group of modulated data signals in place of the modulated data signal, and number of the groups of compensated data signals, demodulated data signals and modulated data signals being equal to or smaller than number of the group of received signals.

In the receiver of this invention, carrier frequencies according to the multi-carrier transmission technique may overlap each other, and the divider may divide the received signal using FFT (Fast Fourier Transformation).

The receiver of this invention may further include an output section.

The output section may restore a data signal included in the transmission signal before being modulated, to its original signal using the group of demodulated data signals, and output the demodulated data signal as a transmission data signal.

In the case where OFDM (Orthogonal Frequency Division Multiplexing) is employed as a multi-carrier transmission technique, the transmission data signal is parallel-serial converted so as to be restored to its original signal.

In order to accomplish the above object, according to the second aspect of the present invention, there is provided a data signal receiving method comprising the steps of receiving, estimating, compensating, demodulating, and modulating.

In the receiving step, a resultant signal obtained by transmitting a transmission signal obtained by modulating a signal including a known signal and a data signal may be received, and output as a received signal.

In the estimating step, transmission path characteristics may be estimated.

In the compensating step, a portion of the received signal which corresponds to the data signal may be compensated using the estimated transmission path characteristics, and output as a compensated data signal.

In the demodulating step, the compensated data signal may be demodulated, and output as a demodulated data signal.

In the modulating step, the demodulated data signal may be modulated, and output as a modulated data signal.

- 5 The step of estimating the transmission path characteristics may include the steps of
- (a) comparing a portion of the received signal which corresponds to the known signal with a resultant signal which is obtained by modulating the known signal, and
 - (b) comparing the portion of the received signal which corresponds to the data signal with a portion of the modulated data signal which corresponds to the data signal,
- 10 thereby estimating the transmission path characteristics.

In the receiving method, a portion of the received signal which has not yet been compensated is compensated using a portion of the transmission path characteristics which have already been estimated.

- In the receiving method of this invention, in the estimating step, impulse responses
- 15 obtained by performing the steps (a) and (b) may be output as transmission path characteristics.

In the modulating step, the known signal may be modulated, and output as a modulated-known signal.

- The estimating step may include the steps (a) and (b) while using a resultant signal
- 20 which is obtained by modulating the known signal.

In the method of this invention, the transmission signal may be obtained by modulating a signal including a known signal and a data signal, using a multi-carrier transmission technique. The method may further include a dividing step.

- In the dividing step, the received signal may be divided at each carrier frequency,
- 25 using the multi-carrier transmission technique, and output as a group of received signals.

The method may use the group of received signals in place of the received signal, a group of compensated data signals in place of the compensated data signal, a group of

demodulated data signals in place of the demodulated data signal, a group of modulated data signals in place of the modulated data signal, and number of the groups of compensated data signals, demodulated data signals and modulated data signals being equal to or smaller than number of the group of received signals.

- 5 In the receiving method of this invention, carrier frequencies according to the multi-carrier transmission technique may overlap each other, and the step of dividing may include a step of dividing the received signal using FFT (Fast Fourier Transformation).

In the step of outputting, a data signal included in the transmission signal before being modulated may be restored to its original signal, using the group of demodulated
10 data signals, and output as a transmission data signal.

For example, in the case where OFDM (Orthogonal Frequency Division Multiplexing) is employed as a multi-carrier transmission technique, the transmission data signal is parallel-serial converted so as to be restored to its original signal.

A program for realizing the receiver and receiving method according to the present
15 invention may be stored in a recording medium, such as a compact disk, a floppy disk, a hard disk, a magneto-optical disk, a digital versatile disk, a magnetic tape, or a semiconductor memory.

The program stored in the recording medium according to the present invention may be executed by a data processor being equipped with a storage device, a computing unit,
20 output device, and the like, such as a general-purpose computer, a video game device, a PDA (Personal Data Assistants), and a cellular phone, to realize the above described receiver and receiving method.

The recording medium storing the program according to the present invention may be distributed or merchandized being separated from the data processor.

25 BRIEF DESCRIPTION OF THE DRAWINGS

The object and other objects and advantages of the present invention will become more apparent upon reading of the following detailed description and the accompanying

drawings in which:

FIG. 1 is an exemplary diagram showing the relationship between a receiver according to the first embodiment of the present invention and a transmitter which transmits a signal to the receiver;

5 FIG. 2 is an exemplary diagram showing the schematic structure of the receiver according to the first embodiment;

FIG. 3 is an explanatory diagram showing the frame format of a known signal, which is transmitted by the receiver of the first embodiment of the present invention, and a data signal;

10 FIG. 4 is an explanatory diagram for explaining a process for estimating transmission path characteristics, which is carried out by an estimator included in the receiver of the first embodiment;

FIG. 5 is an explanatory diagram for explaining a process for estimating transmission path characteristics, which is carried out by an estimator included in a
15 receiver according to the second embodiment;

FIG. 6 is a graph showing an experimental result showing the relationship between a frame length and bit error rate, which is obtained in accordance with a conventional technique; and

FIG. 7 is a graph showing an experimental result showing the relationship between a
20 frame length and bit error rate, which is obtained in accordance with a technique of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Embodiments of the present invention will now be described. One skilled in the art may be able to propose modified embodiments each of which include all or some
25 elements described in the following embodiments of the present invention. Such modified elements will be included in the scope of the present invention, because the following embodiments of the present invention do not limit the scope of the present

invention but just explain the present invention.

First Embodiment

FIG. 1 is an exemplary diagram showing the relationship between a receiver according to the first embodiment of the present invention and a transmitter which
5 transmits a signal to the receiver.

A transmitter 151 accepts a data signal 152, modulates the data signal 152 and a known signal 153 to a transmission signal 154, and sends the transmission signal 154 to a receiver 101.

The transmission signal 154 changes in its form by the influence of a transmission
10 path.

The receiver 101 receives a resultant signal after changed, as a received signal, estimates changeable transmission path characteristics, using a received signal 102 and the known signal 153, and obtains a demodulated-data signal 105 as a transmitted signal.

FIG. 2 is an exemplary diagram showing the schematic structure of the receiver
15 according to the first embodiment. The same reference numerals as those of the elements shown in FIG. 1 are affixed to the same component elements of the receiver shown in FIG. 2.

The receiver 101 comprises a receiving section 201, an estimator 202, a compensation section 203, a demodulator 204, and a modulator 205.

20 The receiving section 201 receives the signal which is transmitted and changed through a transmission path, and outputs the signal as the received signal 102.

The estimator 202 estimates transmission path characteristics 103, using a technique as will be explained later.

The compensation section 203 compensates for a portion of the received signal 102,
25 which corresponds to a data signal thereof, and outputs the compensated portion of the received signal 102, as a compensated data signal 104.

The demodulator 204 demodulates the compensated data signal 104, and outputs the

signal 104, as a demodulated data signal 105. This demodulated data signal 105 is a data signal sent from the transmitter 151.

The modulator 205 modulates the demodulated data signal 105, and outputs the signal 105, as a modulated data signal 106.

5 FIG. 3 is an explanatory diagram showing a frame format of a to-be-transmitted known signal and a data signal. FIG. 4 is an explanatory diagram showing a process for estimating transmission path characteristics, which is carried out by the estimator 202.

One frame 301 includes a known-signal portion 302 for storing the known signal 153 and a data signal portion 303 for storing the data signal 152. The data signal portion
10 303 is divided into an "N" number of data signal portions $303d_1, 303d_2, 303d_3, \dots, 303d_N$, in the unit of packets $d_1, d_2, d_3, \dots, d_N$. As will specifically be described later using an experimental result, even if the length of each of the data signal portions $303d_1, \dots, 303d_N$ is larger than the length of the known-signal portion 302, the receiver 101 according to this embodiment can obtain a preferable experimental result.

15 The estimator 202 divides the known signal 302 of the received signal 102 by a resultant value obtained by modulating the known signal 302, so as to obtain an impulse response corresponding to a quotient of the division. This impulse response is an estimated value of the transmission path characteristics at the time the known signal 153 has just transmitted.

20 In terms of a packet adjacent or close to the known-signal portion 302, the estimated value is not so far away from the actual transmission path characteristics. The compensation section 203 compensates for those data signal portions $303d_1, \dots, d_L$ ($L < N$), of the data signal portions $303d_1, \dots, d_N$, using the impulse response obtained using the data signal portion 302.

25 After the corresponding data signal portions 303 are compensated, the demodulator 204 demodulates the data signal portions $303d_1, \dots, d_L$, thereby to obtain thus demodulated data signal portions $303d_1, \dots, d_L$, included in the data signal 152.

Further, likewise the case of the known signal 153, the last "M" ($M \leq L$) number of the data signal portions 303 are used as data for estimating the transmission path characteristics. Hence, the modulator 205 modulates those data signal portions d_{L-M+1}, \dots, d_L , which are included in the data signal 152, so as to obtain the modulated data signal 106.

The estimator 202 divides the data signal portions $303d_{L-M+1}, \dots, 303d_L$ of the received signal 102 respectively by those data signal portions d_{L-M+1}, \dots, d_L of the modulated data signal 106, so as to obtain impulse responses corresponding to the respective quotients of the divisions. Thus obtained impulse responses are estimated values of the transmission path characteristics at the time the data signal portions d_{L-M+1}, \dots, d_L , are transmitted.

It can be assumed that the estimated value corresponding to the data signal portion d_{L+1}, \dots, d_{2L} , which are close to the last compensated packets d_{L-M+1}, \dots, d_L , is not so far from the actual transmission path characteristics. Now, the data signal portions $303d_{L+1}, \dots, 303d_{2L}$ are to be compensated using the above estimated values.

Similarly, the following procedures (a), (b), and (c) are repeated until the data signal portions $303d_1, \dots, d_N$ are entirely demodulated.

(a) Using the estimated transmission path characteristics corresponding to the data signal portions $303d_{(i-1)L-M+1}, \dots, d_{iL}$, the compensation section 203 compensates for the data signal portions $303d_{iL+1}, \dots, d_{(i+1)L}$, so as to obtain the demodulated data signal 105.

(b) The modulator 205 modulates the data signal portions $d_{(i+1)L-M+1}, \dots, d_{(i+1)L}$ of the demodulated data signal 105, so as to obtain the modulated data signal 106. Using this obtained modulated data signal 106, the estimator 202 estimates the transmission path characteristics.

(c) An integer i is incremented by one.

The integers N , L , and M can be arbitrary values which satisfy the above conditions, or can be any adequate values obtained as a result of experiment adopting an actual

device, etc.

In the case where to estimate the transmission path characteristics using a plurality of packets, i.e. in the case where $M > 1$, a plurality of impulse responses for the respective packets can be derived. Then, an average of the plurality of impulse responses can be
 5 obtained. To find the average of the plurality of impulse responses, the weighted average, wherein the larger the subscript of the data signal portions $d_{(i+1)L-M+1}, \dots, d_{(i+1)L}$, the more the weight added to it, of the data signal portions may be obtained.

The so-far described signal processing may be carried out using not only a high-speed computer, an electronic circuit, which operates under the control of software such
 10 as a DSP (Digital Signal Processor), FPGA (Field Programmable Gate Array), etc., but also an ASIC (Application Specific Integrated Circuit).

The technique for modulating and demodulating the data signal is arbitrary, and is not limited to OFDM (Orthogonal Frequency Division Multiplexing), as will be explained later.

15 Second Embodiment

In the above-described embodiment, the technique for the modulating and demodulating the data signal is not limited. However, in the second embodiment, explanations will now be made to the modulating and demodulating of the data signal using a multi-carrier communications technique (including orthogonal frequency division
 20 multiplexing communications). FIG. 5 is an explanatory diagram for explaining a process for estimating transmission path characteristics, which is carried out by the estimator 202 included in the receiver according to this embodiment.

A signal received by the receiver is divided into a plurality of signal portions at each carrier frequency. In the case of orthogonal frequency division multiplexing
 25 communications, the received signal is divided into a plurality of signal portions at each carrier frequency, using FFT (Fast Fourier Transformation). Additionally, in the case of multi-carrier communications wherein the bandwidths of modulated signals do not

overlap each other, the received signal can be divided using a generally-known filtering process.

In the first embodiment, the signal has been referred to as a single signal. On the other hand, in this embodiment, a group of divided signals are processed in one unit.

- 5 The estimating of the transmission path characteristics and the compensating of the signals are accomplished likewise the above.

In this embodiment, a group of demodulated data signals themselves are not data signals to be transmitted from a transmitter. Hence, the group of demodulated data signals are parallel-serial converted, thereby to obtain a transmission data signal.

- 10 In this embodiment, the known multi-carrier communications, specifically the OFDM (Orthogonal Frequency Division Multiplexing) communications, is expanded with ease, thus realizing a communications technique for transmitting a large amount of data.

Experimental Result

- FIG. 6 is a graph showing a result of an experiment processed using a computer, specifically showing the relationship between a frame length and bit error rate in the case where data is transmitted in accordance with a conventional technique. FIG. 7 is a graph showing a result of an experiment processed using a computer, specifically showing the relationship between a frame length and bit error rate in the case where data is transmitted in accordance with a technique of the present invention. In these graphs, the horizontal axis shows the frame length (burst length), whereas the vertical axis shows the bit error rate.
- 20

- As shown in FIG. 6, the larger the frame length, the more the bit error rate. In the case where the frame length is 300 bits, the experimental result shows that almost 50 percent of transmission data is not satisfactorily transmitted, as a result of a transmission error.
- 25

On the other hand, as shown in FIG. 7, according to the technique of the present invention, the bit error rates of data transmission differ from each other, depending on

compensation intervals (denoted by "nce" in the graph, and corresponding to the above-described value "L") at which the data is compensated. The important thing in this experimental result is that the bit error rates are all less than 10 percent and obviously lower than the bit error rates in the case of data transmission according to the
5 conventional technique.

Various embodiments and changes may be made thereonto without departing from the broad spirit and scope of the invention. The above-described embodiments are intended to illustrate the present invention, not to limit the scope of the present invention. The scope of the present invention is shown by the attached claims rather than the
10 embodiments. Various modifications made within the meaning of an equivalent of the claims of the invention and within the claims are to be regarded to be in the scope of the present invention.

This application is based on Japanese Patent Application No. 2000-154177 filed on May 25, 2000, and including specification, claims, drawings and summary. The
15 disclosure of the above Japanese Patent Application is incorporated herein by reference in its entirety.